Paralleling Temporary Power at the Beijing 2008 Olympic Games

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ABSTRACT: Paralleling temporary electrical power generated within an independently owned facility and the utility power source is not permitted by the China national power bureau. Because of the unique importance of the Olympic Games and the critical need for continuous power to supply the central broadcasting facilities during these games, special approval was obtained to design and provide a system suitable for these needs, but only for the single building which was to serve as the central broadcasting center and known as the IBC (International Broadcasting Center, pictured below). Following is a brief insight and overview of some of the considerations made in order to provide the high level of reliability needed to add the paralleling capability to this switchgear, and meet the demands required by the power bureau and other key entities involved.

Background and Overview

The IBC electrical power distribution system consists of numerous 400V switchgear lineups distributed throughout the facility, the configuration of each is as illustrated in Figure 1 below. The typical main bus scheme provides multi-power sources with backup as sketched. Under normal conditions, the system is powered by main source S1. If the main source is lost, then S1's main breaker opens and the tie breaker automatically closes, connecting backup power S2 to the bus. At the same time, because an abnormal condition exists, the backup emergency generators start-up and serve as backup to S2. The number of actual generators (one, two or three) in operation to serve the bus varies between locations and depends on critical load needs. Wherever multiple generators are provided they are always synched to each other on their common bus prior to possible use. Should source S2 be lost, the generator(s) will provide emergency power to the system. All power sources are intended to run independently, only one source provides power to the system at any given time under the automatic switching conditions described and all critical control is through PLC (Programmable Logic Controller).

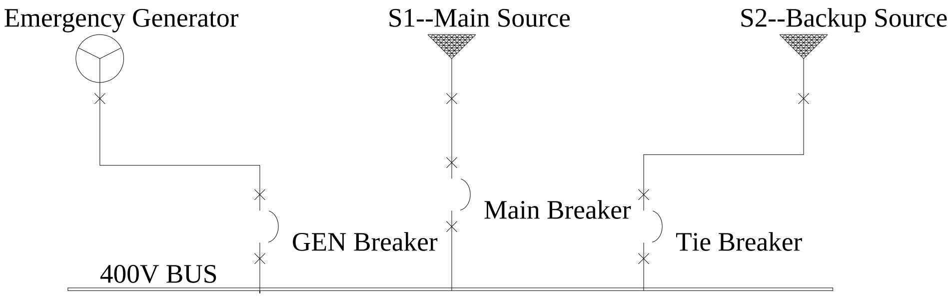

Fig. 1 Simplified Typical IBC LV Switchgear 1-Line

Power loss, unfortunately, does occur on the bus during these emergency-operating conditions. The outage time per switching cycle, including sensing, signal transmissions, and internal trip times, is roughly ten to one hundred milliseconds. Even short disturbances such as these can result in damage and extended outages to these most sensitive critical loads, and impose long restart cycles for their (and other equipment) internal control processes. UPSs were therefore applied wherever possible to assure continuity of high quality power to the most critical loads. The reliability and value of the fundamental power source remained of great concern in such a high visibility application for confident operation under any eventuality including bypass modes.

It was agreed to minimize such outages wherever possible by incorporating a transitional parallel operation mode between sources. That is, paralleling would be permitted, for this application only, and for periods not to exceed a maximum defined length of time. These possibilities existed during power recovery switching cycles: from backup operation mode, returning to the main source, and during test and scheduled maintenance operations. This agreement was far from simple since paralleling the customer’s power system with that of the Power Bureau constituted a change to normal practices and related standards, considerable safety and operational related concerns, and a venture into the potentially risky unknown. Many detailed discussions were conducted between all involved parties over a period of two years. Final agreement occurred several months prior to the actual beginning of the games, and after the installation and startup of the original non-paralleling switchgear had occurred. Revision of the already energized switchgear was carefully planned, implemented in the field with highly reliable factory constructed components and subsystems, and successfully tested under strict scrutiny. Special planning was also required to minimize outages to the building, which was operational and occupied at this time.

The Paralleling Transfer Scheme

The IBC is a large facility with many LV substations, the basic schematic diagram for each is as shown in Figure 1 above. A more detailed diagram of the final revised system configuration is shown in Figure 2 below. A number of items had to be clearly considered to make this project a success:

Controls and Communications

To ensure the reliability, and fast-response time of the control system to the changes and needs of the LV and generator systems, careful consideration was given to the selection of system hardware and communication style. The Multilin F650 protection relay was specified for its wide range of protection and communication functionality as well as control logic and setting flexibility. The GE Fanuc Pac RX3i PLC was chosen to provide all the logic, I/O and fast interface capabilities needed for the system paralleling transfer, and to properly communicate with the generators and their independent PLCs, the Multilin F650 and all breaker controls. Selecting these two key items minimized the number of other control devices typically required for such applications since the F650 (see Figure 3 below) incorporates reverse power and synch-check functions as part of its capabilities in addition to all the metering, protection and control necessary to sense outages, determine load levels, communicate to the PLC’s, and protect the circuits regardless of the direction of power flow. Likewise, the RX3i’s high performance 300 MHz microprocessor-based controllers, 10 Mbytes of user memory, universal programming environment capabilities, and it’s ability to cross multiple hardware platforms, assured everyone the fast response and high reliability needs of this project could be met.

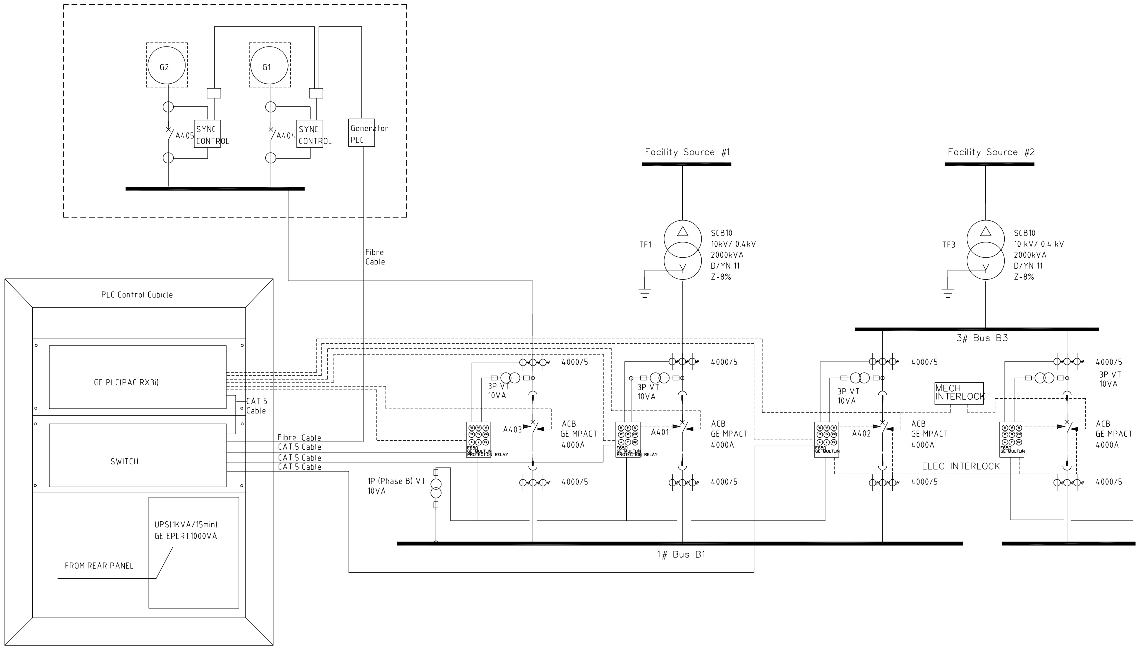

Fig. 2 Simplified 1-Line For Parallel-Capable IBC System

Redundant control power including UPSs was incorporated to supply all critical controls in the newly added and existing circuitry. Because of the large distances separating the LV switchgear from their supporting temporary generator sources, redundant fiber optic communication cables were used here to minimize the need for auxiliary supporting hardware, decrease possible induced interference and assure overall communication reliability between these two isolated but critical parts of the system.

Protection Devices

In a conventional power distribution system, each circuit breaker is required to have its normal complement of protection functions including long time for overloads, instantaneous for short circuits, and others, depending on the application, which may include short-time and GF to

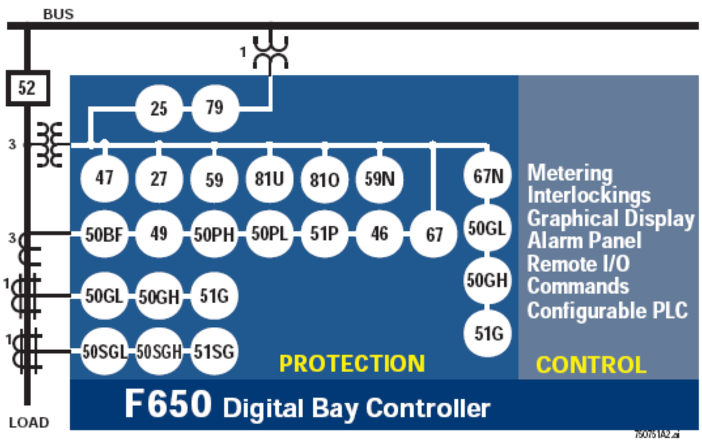

Fig. 3 F650 Function Block Diagram

assist in coordination and earthing protection. When power sources are paralleled, additional protection must be added at various key positions in the system. This protection includes a means of confirming that the voltage magnitude, phase angles, and frequencies between the two systems are within a safe tolerance level. Directional sensing capabilities must also be included in order to limit the flow of power in undesirable directions, and to assure proper coordination in both directions, since the protective settings are usually different in each direction.

The protective functions included within the trip unit of a standard low voltage circuit breaker cannot typically differentiate between the directions of power flow. For this reason its overcurrent settings will trip at the same magnitude whether the load is flowing upstream or downstream. The F650 relays were added to obtain this important capability as well as the many other protection, sensing and communication functions required for this application.

Logic of Paralleling Transfer

The logic for parallel operation must be carefully considered and flow charts prepared. Each breaker must operate as part of a predefined sequence, system conditions and permissives confirmed, and each alternate power source sequenced into its proper standby or primary position in the system depending on its state of operation, the previous and existing conditions. The substation PLC served as the central controller for the main switchgear, gathered all local data, performed all necessary critical control, communicated all interfacing with the standby generators and their controllers, and confirmed all actions. The PLC can also perform load-shedding functions if required and requested.

For this application normal power is supplied by main source S1, the backup power (S2) is in hot standby, and the gensets are under cool-standby. When the main source power is lost, the PLC commands the S1 main breaker to open. Once confirmed and following verification of a sound bus and availability of the alternate source, a close command is sent to close the S2 tie breaker. Power is automatically transferred to the backup source with minimal delay, and the gensets are commanded to start via communications. Within about 15 seconds the genset are available as the hot-standby. Alternative logic must also be provided to assure proper operation and immediate notification if any of these planned operations fail to perform properly.

Separate sequences must also be considered and included for the recovery cycle to permit a return to normal power conditions. For this system, different sequences and methods are incorporated depending on which source is supplying the system at the time of recovery. The process may include the paralleling of either both utility sources or the gensets with the utility source. In either case, verification of safe transfer conditions is confirmed through the protective relaying and sensing, and the period of parallel operation is transitional.

Withstand Verification

A major concern for parallel transfer schemes is that the fault current capacity of the system, which dramatically increases during the period of parallel operation, may exceed the short-circuit ratings of the equipment being paralleled. Appropriate system modeling and evaluations must be conducted to confirm these ratings and their duties are compatible.

Such evaluations were conducted for this application, investigating maximum short current fault conditions of various types and differing system worst-case fault conditions. Below in

Figure 4 is an example of one of the case conditions prepared for the IBC showing only the main LV switchgear. Here three 1250kVA generators are run in parallel and connected to the main switchgear bus. The results show that the maximum three-phase short current can reach 54kA under these conditions, well below these equipment ratings.

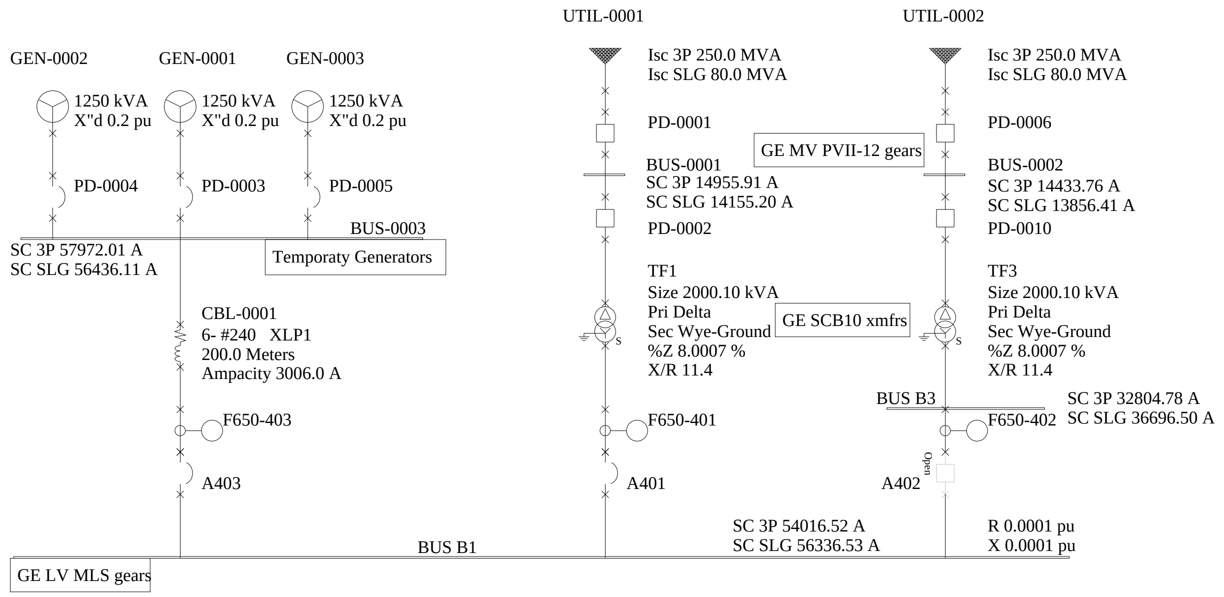

Fig. 4 Short-circuit Model 1-Line

Conclusions

Parallel operation of supply sources within a power system has been shown by many studies to provide added reliability to the overall operation of the power system and may be necessary for certain critical applications. Such operation adds system complexity and requires suitable planning, appropriate system protection and control, and critical evaluation of the system's needs and capabilities. When done properly, however, it is possible to achieve even when the system equipment has already been installed and placed in service. In all cases proper consultations and approvals are necessary.